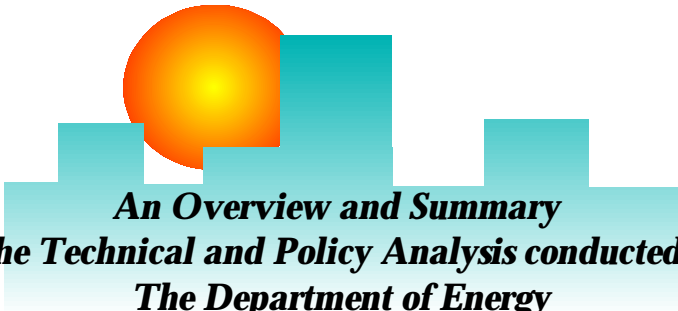




REPLACEMENT FUEL AND ALTERNATIVE FUEL VEHICLE TECHNICAL AND POLICY ANALYSIS

A graphic featuring a bright orange sun rising behind a stylized city skyline composed of several teal-colored rectangular blocks of varying heights.

***An Overview and Summary
of the Technical and Policy Analysis conducted by
The Department of Energy
in partial fulfillment of the requirements of
Section 506 of the Energy Policy Act of 1992.***

July 1997

**United States Department of Energy
Energy Efficiency and Renewable Energy
Office of Transportation Technologies**

DISCLAIMER

This document highlights work sponsored by agencies of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that it would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

INTRODUCTION

What is *The 506 Report*?

Section 506 of The Energy Policy Act of 1992¹ (EPACT) requires the Secretary of Energy to prepare and transmit to the President and the Congress a technical and policy analysis on the development and use of replacement fuels and alternative fueled vehicles. This analysis shall be based on the best available data, and on experience, and shall evaluate:

- (1) progress made in achieving the fuel displacement goals described in the act;
- (2) the actual and potential role of replacement fuels and alternative fueled vehicles in significantly reducing United States reliance on imported oil; and

(3) the actual and potential availability of various domestic replacement fuels and alternative fueled vehicles.

This paper summarizes the first of the two technical and policy analyses required by EPACT. It includes all of the elements that the Department of Energy (DOE) is required to evaluate. It also includes a discussion of some additional issues and perspectives identified by the DOE which were not specifically suggested in the law.



¹ Public Law 102-486

BACKGROUND

Energy Security Concerns

Production of oil by petroleum exporting countries was reduced by 4 to 5 million barrels per day in 1973-74 and again in 1979-80. In both cases, world oil prices more than doubled. OPEC members kept production at lower levels in the subsequent years, and prices remained at the new, higher levels.



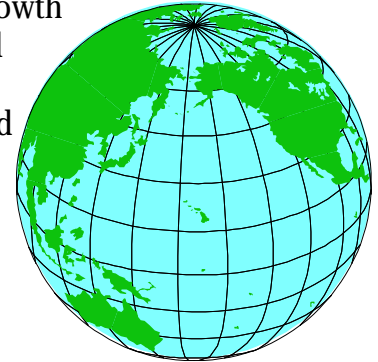
A common sight at service stations during the 1973 oil embargo

Following the Iraqi invasion of Kuwait in 1990, oil output fell and oil prices again nearly doubled. This latest price shock was short-lived, however, as Saudi Arabia put its slack capacity to use, making up most of the lost supply.

The geopolitical setting surrounding energy security has changed enormously since these oil price shocks. The Cold War has ended, OPEC is in disarray, and the U.S. has cemented security ties to the most important oil exporting nations. Unfortunately, these developments, along with low oil prices for the past decade, have produced a sense of comfort on the

part of the American public similar to that which preceded the previous oil shocks.

Economic realities and trends are setting the stage for a potential oil shock sometime in the future. Economic development in the Pacific rim is contributing to a growth in world oil demand that could outstrip the growth of world capacity. In addition, the major oil sources developed within the western world (North Sea and Alaska North



Slope) during the '70s and '80s are expected to start ebbing, as are some other non-OPEC sources. These conditions increase the possibility of an oil supply shortage within the next five to ten years.

The costs to the U.S. economy from a future oil price shock could be enormous. Based on analyses of previous oil shocks, a number of recent studies have estimated that an oil price shock could reduce U.S. economic activity by an average of over 2% per year for four years or more. This means reductions to U.S. GNP in the hundreds of billions of dollars!

Moreover, U.S. national security is directly related to the security of its energy supplies. For example, the 582,000 U.S. forces deployed during Operation Desert Storm consumed more than four times the daily use of the entire 2 million person Allied

Expeditionary Force in World War II Europe. The ability to deploy forces around the globe rapidly, requiring highly intensive energy use, is one of the fundamental pillars of the new strategic framework.²

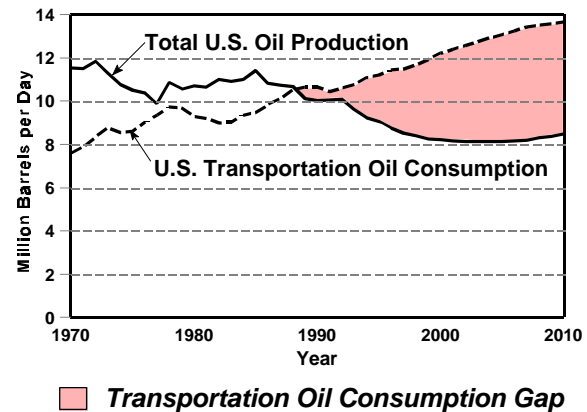
The Critical Role of Transportation

U.S. energy use has changed dramatically since the oil supply and price shocks of the 1970s. Our economy, technology, and consumption patterns have responded by reducing consumption, increasing efficiency, and diversifying energy types. The single major exception has been the transportation sector.

Federally mandated fuel economy standards have cut average new-car fuel consumption in half since 1974. Nonetheless, the amount of petroleum consumed by transportation continues to rise due to the increasing number of miles being driven every year. And, unlike other sectors of the economy where mixes of fuels have emerged, the transportation sector remains overwhelmingly dependant on petroleum-based fuels. About 97.5% of transportation energy comes from petroleum.

The transportation sector accounts for about two-thirds of the petroleum used in the U.S. - roughly one-fourth of all the

energy consumed. Petroleum used in transportation alone exceeds total domestic oil production by 2 million barrels per day. This gap is growing, and is projected to reach nearly 6 million barrels per day by the year 2010, as shown in the accompanying graph. And every additional gallon of gasoline consumed requires even more imported oil!



Energy for transportation truly represents one of the major sources, if not the single major source, of short- and medium-term vulnerability for American society and the American economy today.

Substitution of non-petroleum fuels ("replacement fuels," including alternative fuels such as electricity, ethanol, methanol, hydrogen, liquefied petroleum gas, and natural gas) for petroleum-based transportation fuels (gasoline and diesel) could be a key means of reducing the vulnerability of the U.S. transportation sector to disruptions of the petroleum supply.

² *Natural Gas Vehicles: Helping Ensure America's Energy Security*, The National Defense Council Foundation, 1995, p.4, citing *Oil and War*, Robert Goralski, William Morrow & Co., 1987; *Moving Mountains: Lessons in Leadership and Logistics from the Gulf War*, Lt. Gen. William G. Pagonis, Harvard Business School Press, 1991

FINDINGS

Progress Toward Meeting The EPACT Goals

Section 502(b)(2) of EPACT suggests goals of displacing 10% of transportation fuel with replacement fuels by the year 2000 and displacing 30% by the year 2010.

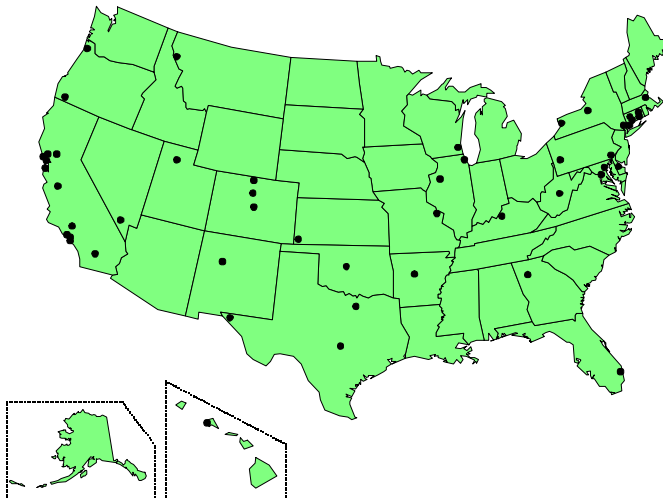
DOE is making steady progress in carrying out the provisions of EPACT Title V and related programs, which should yield measurable results in alternative fuel and AFV use in the future. For example:

- ❑ DOE supports and coordinates the Federal Fleet Program for acquisition of AFVs. At the end of 1995 this program had put over 20,000 AFVs on the road for Federal agencies, including the U.S. Postal Service, the Department of Defense, and the General Services Administration.

This program has dramatically increased the use of important classes of AFVs, has prompted automakers to expand AFV availability, and is encouraging the alternative fuel industry to plan and invest in a growing refueling infrastructure.

- ❑ DOE's **CLEAN CITIES Program** promotes voluntary commitments by key groups within participating city regions to acquire AFVs and to install alternative fuel infrastructure. The "grass-roots" approach of Clean Cities is designed to provide an effective plan, carried out at the local level, for creating a sustainable, nationwide alternative fuels market.

As of the fall of 1996, there were 50 designated CLEAN CITIES, spanning the country from Honolulu to Boston to the Florida Gold Coast, encompassing a population of more than 70 million.



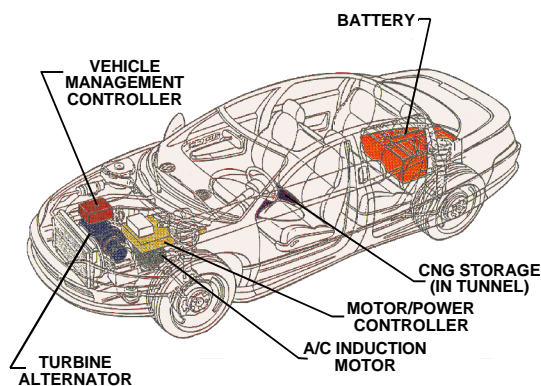
Designated Clean Cities

Over 1,000 stakeholder organizations, including government entities, private fleets, and AFV and alternative fuel providers are participating.

- ❑ DOE is also carrying out rulemaking and analytical activities prescribed by EPACT Title V. Regulations governing the Alternative Fuel Provider Mandate (EPACT sec. 501) and the Mandatory State Fleet Programs (EPACT sec. 507(o)) were published in the *Federal Register*. An Advance Notice of Proposed Rulemaking for a possible private fleet mandate (EPACT sec 507(b)) has also been published.

Among its analytical activities, DOE is assessing the technical and economic feasibility of reaching EPACT's 10% and 30% fuel displacement goals. In addition, The Energy Information Administration (EIA) annually estimates the number and geographic distribution of each type of AFV in the U.S., as well as the amount of each type of alternative fuel distributed.

- ❑ Research, development, and demonstration programs foster technology development in two spheres. The **Advanced Vehicle Propulsion Technologies Program** is pursuing research in hybrid propulsion systems, transportation fuel cells, improved energy storage technologies, advanced heat engine technologies, and advanced materials. One hybrid vehicle concept is



shown below.

The **Alternative Fuels Research and Demonstration Program** is conducting several R&D projects to lower the cost and improve the performance of vehicles that use alternative fuels, assist the introduction of alternative vehicles/fuels that can be competitive with conventional fuels and vehicles,

and develop technologies to provide abundant, cost-effective fuels from domestic resources. The program is now turning its focus to alternative fuels infrastructure technology.

- ❑ DOE is also involved with EPA in Clean Air Act programs that promote use of advanced technology vehicles, including alternative fuel vehicles, in ozone non-attainment areas.

Many of the programs authorized by EPACT have not been in place long enough to allow a credible assessment of their impact. In fact, this Technical and Policy Analysis is being released before the start of many of the EPACT programs.

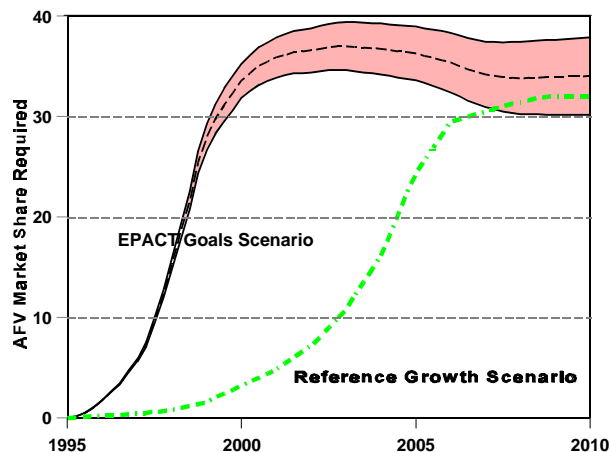
Role of Replacement Fuels and AFVs in Reducing Oil Imports

DOE modeling suggests that the potential for use of replacement fuels in the U.S. is very high; the market could support replacement of as much as 30 - 38% of light duty vehicle fuels by the year 2010. But the transportation sector has barely begun to realize this potential, and in 1996 the use of replacement fuels is estimated by EIA to be only about 3.1% of total highway transportation fuel. Most of this, 2.9%, was oxygenates blended into gasoline and only about 0.2% was alternative fuel use by AFVs.

Analysis indicates that currently authorized Federal, state and local AFV programs could displace roughly 3% of the LDV transportation fuel use projected by EIA for 2010. Replacement fuels in the form of oxygenates could contribute an additional

4.8 - 6.7%. The gap between these volumes and those necessary to reach or approach the EPACT goal of 30% fuel displacement by 2010 would have to be met by AFV use by the general public.

Reaching the EPACT goals would require a very high rate of AFV sales. The graph below shows the share of new car sales through the year 2010 which would need to be AFVs in order to meet these goals. (The shaded area represents the range between the high and low values calculated by the model.)



This rate of market penetration is much more rapid than the typical pattern for auto industry introduction of new models or new technologies.

An alternate AFV acquisition scenario, known as the *Reference Growth Scenario*, presents a more gradual phase-in of AFVs. The AFV introduction rate required by this scenario is also illustrated in the graph. This rate of AFV acquisition is believed to be more representative of the introduction of new vehicle technologies into the market, but is still enormously ambitious.

Under this scenario, the AFV population in 2020 (ten years later than the EPACT 30% goal) would be large enough so that 30% of LDV motor fuel would be replacement fuel (alternative fuels plus oxygenates used in conventional vehicle fuel).

A Role for Fleets

Centrally fueled fleets are considered to be critical to the transportation sector's transition to alternative fuels and vehicles. These fleets, which usually refuel at a central facility and operate within a fuel tank's driving range of that facility, should be amenable to the introduction of alternative fuels.

Congress recognized the opportunities for alternative fuel use by centrally fueled fleets. It included, as part of EPACT's core, Title V, which focusses on displacing conventional fuel by non-petroleum fuel in light duty motor vehicle fleets.



NGVs refueling at a central facility.
(Photo courtesy of Washington Gas Co.)

Title V mandates certain fleets to acquire AFVs. These mandates are not intended to provide major reductions in U.S. petroleum use. Instead, they are intended

to pave the way for alternative fuel use and fuel flexibility by demonstrating the practicability of the technology on a substantial scale. They are also designed to accelerate the development of an alternative fuel refueling system infrastructure. These fleet operations would also provide the necessary critical mass to catalyze U.S. industry into making alternative fuels and vehicles readily available at competitive prices. In this way, the Title V programs would plant the seeds for growth of alternative fuel vehicle use.

The EPACT fleet programs represent a unique approach compared to alternative fuel vehicle programs tried in other countries. This international experience has shown that spillover into voluntary use of alternative fuels and AFVs by individual citizens is likely to be determined primarily by the economic benefits. Merely putting in place a limited infrastructure is not likely to generate high levels of spillover, even when motorists are aware of the benefits to society.

Applying these lessons to the U.S. environment suggests that changes in the overall economics, access, and convenience will be necessary for AFV penetration in the general public. Such changes could occur in various ways, including policy induced changes, cyclical price swings or market disruptions.

Availability of Replacement Fuels and AFVs

Alternative fuel vehicle technologies are available for the principal alternative fuels

believed most likely to play major parts in any transition to substantial alternative fuel use. Alcohol, liquefied petroleum gas (LPG), and natural gas vehicle technologies are sufficiently developed for such vehicles to be introduced into the market on large scales.

Electric vehicle technology is also close to market-ready, but battery cost and range probably limit penetration to select market niches for the next five to ten years. Hybrid electric, fuel cell, and hydrogen vehicle technologies are in various stages of development and could play significant roles in the future, but probably not before 2010.

A number of types of AFVs are currently available for purchase from original equipment manufacturers (OEMs):

- ❑ Passenger cars are available for use with 85% alcohol/15% gasoline mixtures or any mixtures down to straight gasoline, at the same price as the same conventional model. A photograph of a 1996 model-year flexible fuel Ford Taurus is shown below.



1996-model flexible fuel Ford Taurus

- ❑ A pickup truck may soon be available for 85% ethanol use.
- ❑ Pickup trucks and full-size vans are available for dedicated and bi-fuel CNG use. A full sized sedan is available for dedicated CNG operation and others may follow.
- ❑ LPG full-size pickups are available in bi-fuel configurations. Medium-duty trucks have been available in dedicated propane configurations.
- ❑ Electric vehicles will soon be available, mostly sub-compact and small pickup models. Shown in the photograph below is the General Motors EV-1, which became available for lease in California and Arizona in Model Year 1997.



General Motors' EV-1 electric vehicle

AFVs may also be obtained by converting conventional vehicles. Cars, pickups, and vans can all be converted to dedicated or bi-fuel CNG or propane operation by hundreds of conversion firms. Conversions of cars and pickups to electric operation are also available.

Alternative fuel refueling sites, such as the publicly-accessible CNG refueling station shown in the following photo, have been proliferating in recent years. (There were

over 1,000 CNG and 3,000 LPG refueling stations operating as of 1995.) However, none of the alternative fuels are currently available at retail in adequate networks to support widespread AFV use. Adequate refueling sites could be available as a transition proceeds but would involve additional capital costs.



Public CNG fueling facility in Beltsville, MD

All of the major alternative fuels are available at national and regional levels in volumes sufficient for transportation use at levels significantly greater than the current levels. While this available supply includes both domestic production and imports, domestic supply will be adequate to serve AFV needs for coming years. If alternative fuel use were to approach the levels suggested by the EPACT 30% goal, market pressures could, however, change the split between domestic and import supply.

Natural gas, ethanol and electricity have the greatest potential for domestic production to meet large scale transportation use. LPG and methanol could be available in adequate quantities either domestically or internationally.

KEY ISSUES AND PERSPECTIVES

Available evidence indicates that substantial spillover from EPACT Title V programs into household AFV acquisitions is unlikely in the absence of some economic additional incentives to make the shift. Such incentives might occur in any one of a number of ways, not necessarily by a government incentive program.

An oil price rise could well cause dramatic changes in relative prices between gasoline and a number of alternative fuels. This could result in natural fuel switching, if the conditions enabling motorists to switch fuels were in place. Experience has shown that a price spike is unlikely to result in major fuel switching in the transportation sector unless both the AFVs and a fuel infrastructure are in place. These are issues which EPACT Title V begins to address.

Developing a fuel switching capability also has the potential to alter the behavior of primary fuel suppliers. If viable competing fuels are available, the likelihood of a restriction of oil supplies could be diminished. Since key OPEC members know that a spike in oil prices leads to subsequent declining and depressed prices, they should give strategic consideration to how high prices can go and how long they can be sustained before causing the large

scale introduction of substitutes. The better the perceived potential of the U.S. to introduce alternatives in the event of an oil price increase, the less the likelihood and/or magnitude of the price increase likely to be sought by OPEC members.³

It is also possible that a well designed EPACT-initiated process of fuel switching could avoid or reduce the magnitude of problems involved with the relatively abrupt technological transitions in transportation that have characterized

historical fuel switches.

Alternative fuel transportation systems could be more fully ripe for widespread deployment and the American public more amenable to fuel switching as results of EPACT fleet programs (as well as DOE

RD&D programs). It may never be possible to know with certainty the actual contributions of the EPACT programs in these "insurance policy" roles.



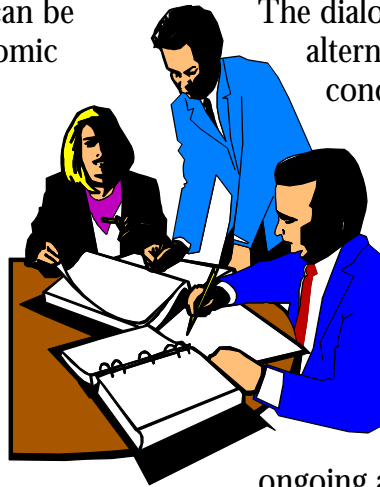
³ While the U.S. share of world oil imports and its importance in the world oil market are likely to be less in the next century than in the 1970s and 80s, U.S. leadership in alternative transportation fuel policy and technology development could well catalyze similar developments in other importing countries.

Making a transition to substantial use of replacement fuels could impose considerable costs on the U.S. economy. These costs are not of the same magnitude, however, as the cost of a potential oil shock, let alone an oil shock with resulting recession. Various reasons exist to suggest that transition policies can be designed to avoid adverse economic impacts, though doing so could possibly delay attainment of the EPACT goals.

Despite the many uncertainties, it preliminarily appears that the programs authorized by Congress in EPACT will fall substantially short of the year 2010 goal of 30%. DOE may need to modify this goal, possibly by rolling back the target dates. EPACT (sec 504) provides ample flexibility for DOE to modify the ambitious statutory goals.

In light of the great magnitude of consequences at stake, it would be prudent

for DOE and interested committees of Congress to begin discussions now on possible additional programs and authorities which would contribute to reaching or more meaningfully approaching EPACT goals.



The dialog might well involve various alternative concepts, and mixes of concepts, of energy security and fuel displacement. Possible roles for AFVs and a refueling infrastructure in establishing capabilities for fuel switching in contingency situations and for demonstrating (to oil exporters) a credible capability to switch might be considered as partial substitutes for actual ongoing alternative fuel use. In any event, given the obvious need for further clarity and continuity in Federal policy, early engagement in such a dialog by the Executive Branch and the Congress (as well as the public) appears to be a pressing imperative at this critical juncture.

FOR MORE INFORMATION

EREC, the **ENERGY EFFICIENCY AND RENEWABLE ENERGY CLEARINGHOUSE** provides phone, mail, and electronic responses to inquiries about DOE's alternative fuel transportation programs.

Phone: 1-800-DOE-EREC (363-3732)

TDD: 1-800-273-2957

Fax: 1-703-893-0400

Computer Bulletin Board: 1-800-273-2955

Internet Electronic Mail: energyinfo@delphi.com

EREN, the **ENERGY EFFICIENCY AND RENEWABLE ENERGY NETWORK** provides users of the World Wide Web another gateway to information and resources:

<http://www.eren.doe.gov>

NATIONAL ALTERNATIVE FUELS HOTLINE AND DATA CENTER is a source for information on issues related to alternative transportation fuels.

1-800-423-1DOE (423-1363)

On the World Wide Web: <http://www.afdc.doe.gov>

The **CLEAN CITIES HOTLINE** may be contacted to obtain information on issues related to the CLEAN CITIES Program.

1-800-CCITIES (224-8437)

On the World Wide Web: <http://www.ccities.doe.gov>

RELATED PUBLICATIONS

EPACT INITIATIVES FOR ALTERNATIVE FUEL VEHICLES, U.S. Department of Energy, Office of Transportation Technologies, March 1995.

ALTERNATIVE FUEL VEHICLES FOR STATE GOVERNMENT & FUEL PROVIDER FLEETS (A Guide to 10CFR Part 490), U.S. Department of Energy, Office of Transportation Technologies.

REPLACEMENT FUEL AND ALTERNATIVE FUEL VEHICLE TECHNICAL AND POLICY ANALYSIS (Pursuant to Section 506 of the Energy Policy Act), DRAFT, U.S. Department of Energy, Office of Transportation Technologies.

MARKET POTENTIAL AND IMPACTS OF ALTERNATIVE FUEL USE IN LIGHT-DUTY VEHICLES: A 2000/2010 ANALYSIS. Technical Report 14 in the Flexible and Alternative Fuel Series, U.S. Department of Energy, Office of Policy and Office of Energy Efficiency and Renewable Energy, January 1996.

ALTERNATIVE FUEL TRANSPORTATION PROGRAM, 10 CFR Part 490, *61 Federal Register* 10622, March 14, 1996.

ALTERNATIVES TO TRADITIONAL TRANSPORTATION FUELS: AN OVERVIEW, U.S. Department of Energy, Energy Information Administration, Report DOE/EIA-0585/O, June 1994.

ALTERNATIVES TO TRADITIONAL TRANSPORTATION FUELS 1993, U.S. Department of Energy, Energy Information Administration, Report DOE/EIA-0585(93), January 1995.

ALTERNATIVES TO TRADITIONAL TRANSPORTATION FUELS 1994, VOLUME 1, U.S. Department of Energy, Energy Information Administration, Report DOE/EIA-0585(94)/1, February 1996.

ALTERNATIVES TO TRADITIONAL TRANSPORTATION FUELS 1994, VOLUME 2: Greenhouse Gas Emissions, U.S. Department of Energy, Energy Information Administration, Report DOE/EIA-0585(94)/2, August 1996.



printed on recycled paper